"Management and Control of Cost and Risk for Tunneling and Infrastructure Projects"

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ABSTRACT

This paper presents a recently-developed risk-based method for the estimation and management of cost for complex, infrastructure projects. Chronic problems in estimating realistic cost estimates for complex infrastructure and tunneling projects are referenced. A methodology to better estimate the cost of such projects, developed by the author and others, and implemented by the Washington State Department of Transportation (WSDOT), is described.

The procedure, called the Cost Estimate Validation Process, or CEVP® [1] uses risk and uncertainty methods to structure a project cost estimate to produce a "range of probable cost". The concept incorporates principles similar to those which have been applied to several specialized tunneling projects using risk analysis processes.

The procedure has been applied to a set of infrastructure projects in Washington State (USA), estimated at about US $25 billion, and to many smaller projects. The process includes explicit identification of high-cost and schedule risk drivers – leading to an ability to develop explicit risk management plans early in a project's development, directly from the CEVP process. Initial results are favorable, with the first public tender falling within the estimated "range of probable cost".

1. MANAGEMENT PROBLEMS – INDICATED BY POOR COST PERFORMANCE

Recently an international editorial asked "Why can't engineers prepare more reliable construction estimates?"(Tunnels & Tunneling, 2003). In the same issue, Fred Salvucci – former Secretary of Transportation for Massachusetts and architect of Boston's 'Big-Dig' – gave us his perspective on the major reasons for schedule slip and cost growth of that project (Salvucci, 2003). The reasons had much to do with Governmental policies, local and national politics, new requirements not planned for in the beginning and, political and management transitions that disrupted continuity. Technical complexity was a factor – but it was not the major cause of the schedule slip and cost growth.

There are many examples of large cost growths for complex projects – the problem is world-wide and it has existed for a long time (Flyvbjerg, 2000) – probably since the very first construction projects. Prominent examples include the Great Belt Link (cost growth +54% over budget), London's Jubilee Line extension (+67%), Boston's Central Artery (unknown yet, but at least 100%, probably 200%) and the Channel Tunnel (+80%). For the purpose of these numbers, cost growth is defined as the final cost less the cost estimated at time of decision to proceed with the project, divided by the estimated cost, in percent. It should be noted that these are all very good and very useful projects - with great

[1] CEVP® is registered to the Washington State Department of Transportation to recognize its development and application of this new process and to assure that, if the process is applied by others, that they acknowledge WSDOT and follow the basic requirements of the process. Hereafter CEVP will be used in the text.

design and construction achievements, all well recognized – for example: "The extended Jubilee Line is attracting high levels of use and has received many prestigious awards." (Arup, 2000).

An international survey by one of the authors (Reilly & Thompson, 2001) listed 1,400 projects world-wide, selected 160 for further enquiry and then looked at 40 which represented a spectrum of project types and locations. It was found that specific, relevant information was very difficult to obtain – good data is very difficult to get because, once projects are completed, the records related to the projects are either archived or dispersed among the project participants.

However, the owners reported that there were significant cost and schedule overruns, suggestive of deficient management, in at least 30% and probably more than 50% of the projects. These results, with examples, were presented at subsequent conferences (Reilly, 2002) with some skepticism from the audiences at that time regarding the pervasive nature of the problem. To address this issue, the Authors would like to focus on the following topics to illustrate promising developments for better management of cost and risk:

- Risk Identification and Mitigation,
- Better cost estimating including risk and,
- A strategy for better cost management including risk.

2. RISK IDENTIFICATION AND MITIGATION

Risk always exists in the design, procurement, construction and operation of large, complex projects, particularly those involving underground conditions (ITA 1992; Jubilee Line 1993; Vrijling and Redeker 1993). Additionally, a significant number of projects have overrun their budgets and schedules through what have been called "unforeseen" events – an excuse frequently given to Agency Boards of Directors when additional time and money are required.

Risk reduction (with related cost and schedule control) through risk identification, analysis, mitigation and contingency planning is therefore a prudent and necessary management task. There are well-established risk identification and management procedures – and there are models for quantifying risk and the derivative cost and schedule probabilities (Einstein and Vick 1974; Roberds, 1996; Grasso, et. al. 2002; Anderson et. al. 1999, Isaksson 1998 & 2002; Reilly 1999 & 2003a). These models have been successfully applied to several, mostly European, tunnel projects.

2.1 Risks for complex infrastructure and underground projects

Infrastructure and underground projects are inherently complex projects with many variables including uncertain and variable ground conditions. The type of risks that should be addressed for such projects include:

- Risk of injury or catastrophic failure with the potential for loss of life, and personal injury, extensive material and economic damage and, loss of credibility for those involved
- Risk of not meeting functional design, operational, maintainability and quality standards
- Risks of a significant delay to project completion and start of revenue operations
- Risks of significant increase of project and support costs

Why do we really need to investigate risk events early in the project life? Reasons include:

- To reduce the risk to project goals and objectives - safety, schedule, budget.
- To demonstrate that options were comprehensively and rationally evaluated
- The process will reveal useful information even if threats do not eventuate
- To clarify internal project goals, objectives and priorities and focus the project team
- Probable ranges of cost and schedule can be estimated

- Risk Mitigation Plans can be developed
- A strategic approach to the project can be defined and implemented early

3. A BETTER COST ESTIMATING PROCEDURE:

In meetings with colleagues and Associations in 12 countries between 1998 and 2002, the need for better management of complex projects was a consistent topic – and managing to budget considered one of the most difficult factors. From these discussions, it was apparent something new was necessary – but what could that new something be?

As noted previously, as a profession, we have consistently been under-estimating the cost of significant projects for a long time. Additionally, we have not corrected this problem because, if we had done so, there would have been a statistical scatter of cost estimates equally above and below the corresponding budget number – but this is significantly not the case (Flyvbjerg 2002).

The process of technical risk identification is well understood and has successfully been applied to a number of projects. Additionally, specialized examples of tunneling risk models, which predict probable cost and schedule ranges, have been developed and successfully used (as noted above). However, risk processes related to probable cost and schedule have not been widely applied to cost estimating for complex infrastructure projects. Such a procedure is described following - in general:

1. The final cost of a project is subject to many variables, assumptions and conditions
2. These variables significantly influence the range of "probable projected cost"
3. A single cost number represents only *one possible result* and is dependent on the variables
4. The variables are not all directly controllable or absolutely quantifiable
5. Better cost estimating must include potential risks and opportunities

It is apparent that managing a project within an established budget means two things:

1. The budget must be realistic in terms of the project, its environment and its characteristics
2. Management procedures must be capable of controlling the project with respect to budget

Traditional methods for dealing with project risk, in terms of cost, rely on the inclusion of "contingencies". These contingencies usually lump together the consequences of an unspecified number and type of potential problems. While based on the judgment of the estimators, these contingencies do not allow for explicit identification and management of project uncertainties and risk.

Additionally, control is difficult of long-term external factors, such as pressure on politicians to include additional scope elements and management transitions caused by political and other factors.

3.1 The Washington State Department of Transportation's Cost-Risk process (CEVP)

In 2000 public skepticism in Seattle, Washington, USA regarding reliability of cost estimates, was yet again confirmed by the very large difference between Sound Transit's cost estimate for its North Extension Light Rail Line and the contractor's price. The Washington State Department of Transportation (WSDOT), led by Secretary Doug MacDonald, was about to initiate several very large Highway projects. Concerned about the referenced cost estimating problem, the Department decided to apply a new, experimental cost estimating process using cost validation and risk assessment.

The "Cost Estimate Validation Process" (CEVP) was developed by a small concept team of WSDOT Managers and Consultants (Reilly, McBride, Dye & Mansfield, 2002). The process includes the effects of all foreseeable risk (and opportunity) events. After initial definition it was directly applied to 9 large complex, transportation projects, with a collective value about $US 25 billion, by WSDOT and the concept team, with other consultants (Brown, 2002). This was development by implementation.

CEVP produced new cost-ranges for these projects which were, not surprisingly, significantly higher than previous cost estimates – due to the inclusion of a comprehensive list of risk events, including potential political and long-range management problems. This produced what was described as "sticker shock" when WSDOT released the results to the public, the press and political decision makers on June 3rd, 2002 (MacDonald et. al. 2002).

However, the "sticker shock" quickly turned to public acceptance of this new way of estimating, as shown by several newspaper articles, editorials and letters. The idea that a cost estimate should not be a single number but a "range" was quickly understood and the Department was commended for producing more realistic cost estimates. One editorial commented: "*Shocking or not, the Department of Transportation has performed an unprecedented public service with these latest cost estimates. It is a much-needed dose of fiscal reality. The department offered realistic cost-range estimates.*"

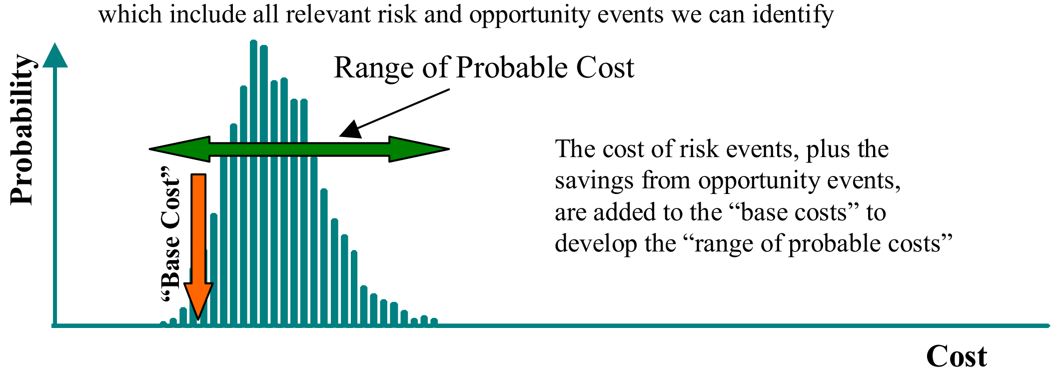
3.2 A summary of the CEVP approach

CEVP is conceptually simple, although complex in application. It consists of the following steps:

1. Examine, in detail, the project estimate and determine the project's "base" costs (those costs that would occur if all goes "as expected") removing all variability and risk ("contingencies") in a concentrated workshop using national and international experts working with the project team
2. Identify potential risks and opportunities with their probabilities and consequences (potential impacts and benefits)
3. Combine base costs, risk and opportunity events to estimate probable ranges of cost and schedule

The essential concept is shown in the Figure below.

- ❑ In the beginning, there is a large potential range for "ultimate cost"
- ❑ The "ultimate cost" will depend on the outcome of many factors
- ❑ We can't predict exactly - but we <u>can</u> develop probable ranges of cost which include all relevant risk and opportunity events we can identify



<u>Figure 1</u> – Base Cost + Risk and Opportunity Costs gives Range of Probable Cost

3.3 Current status of the CEVP Cost Estimating Procedure

Both the CEVP process and a simpler process called Cost-Risk-Assessment (CRA) are currently being applied to other projects in Washington State. Recently, an update of the 2002 results was presented to the State Transportation Commission (MacDonald et. al. 2003) followed by a press conference – which focused on the changes made to the projects to enable them to be constructed within reasonably available funding – rather than the CEVP process itself which was, by then, well understood in Washington State.

After one year, the CEVP process is now taken for granted in Western Washington State as the way cost estimates should be produced. Externally to the State of Washington, the process is being applied by the Transportation Risk and Uncertainty Evaluation consultant group (TRUE, 2003). In January 2003, a briefing was given by the author and Secretary of Transportation MacDonald to the Transportation Research Board in Washington, D.C. (Reilly, 2003a) which included specific briefings to representatives of the U. S. Federal Highway and Federal Transit Administrations. Following this presentation, in July 2003 the U.S. Federal Transit Administration evaluated the CEVP process by applying it to a transit project in Pittsburgh, the North-Shore Connector light rail project. FTA (and the Federal Highway Administration, FHWA) are now planning to require such a cost-risk process to be used for all future cost estimates, as a matter of policy, for all large, complex transportation projects under their jurisdiction.

3.4 Understanding the extent of the cost estimating and management problem – the Flyvbjerg study

Following implementation of the WSDOT CEVP process, in June of 2002 Flyvbjerg et. al. published a study of 258 projects world-wide (Flyvbjerg 2002) which showed the cost estimating problem to be more extensive and chronic than many had believed. Subsequently they stated that “A main cause of overruns is a lack of realism in initial cost estimates.” (Flyvbjerg et. al., 2003). That is, it’s inevitable if the real scope (including the effects of risk events) is greater than that envisioned by the estimator then no manager, however excellent, can manage to an impossibly low estimate. This leads to the third topic of this article – better strategy and management for complex infrastructure and underground projects.

4. STRATEGY FOR BETTER COST MANAGEMENT, INCLUDING RISK

After the London Jubilee Line Extension project was complete, the oversight Consultant’s report to the UK Secretary of State regarding cost and schedule overruns (Arup, 2000) noted that the project was a “…safe achievement, bringing significant benefits.” but that “…time and cost overruns could have been minimized with a more established strategy at the very beginning of the project”. They stated that London Underground Limited (LUL) “…lacked (early) strategy, structure and continuity of management to ensure the delivery of a working railway.” LUL agreed.

Many will agree that an early, comprehensive strategy is necessary for complex projects – but, how can such strategies be explicitly developed? It turns out that one of the “not so secondary” benefits of the CEVP approach is that it forces the project team to think about <u>all</u> risks and, in particular, long-range risks that may not be technical in nature – such as politics, local and national policies, governance issues and management continuity – all major contributors to Boston’s ‘Big-Dig’ cost and schedule overruns (Salvucci, 2003).

Following are the general risk mitigation steps which produce a more strategic approach to risk and successful project management earlier in a project's development – for which CEVP provides explicit data. See also (Reilly, 2003a & b).

1. Identify the high-cost and schedule risk drivers
2. Identify a risk mitigation strategy and formalize in a Risk Management Plan.
3. Implement the risk mitigation strategies to reduce potential impacts – leaving "residual risk"
4. Decide how to handle the "residual risk" – accept, allocate contractually or insure.

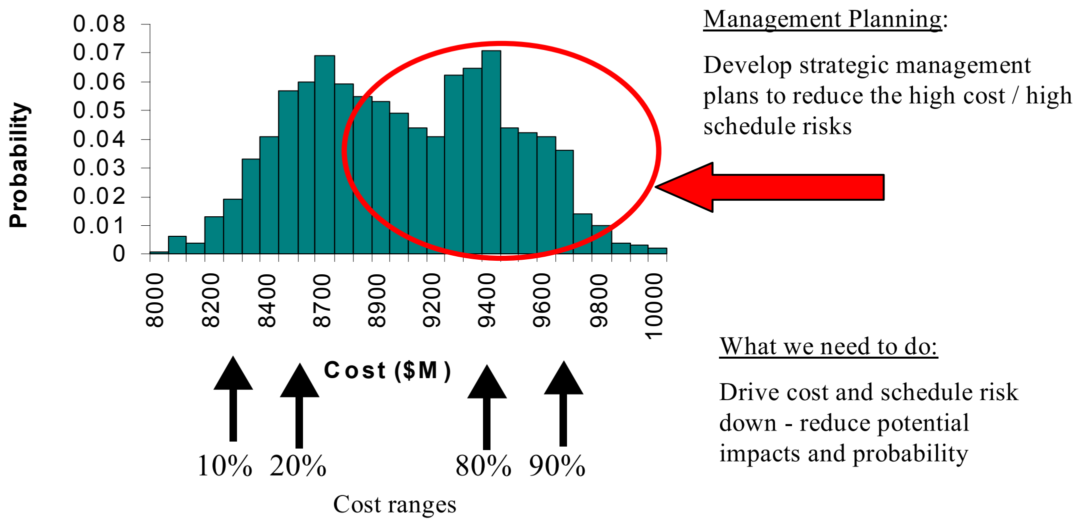


Figure 2 – Range of probable cost with risk mitigation targeted to the high-cost risk events

There are examples, which could be described, of the strategic decisions identified from the CEVP cost estimates – such as changes to the Hood Canal Floating Bridge replacement project and management changes to the governance structure of the Seattle Monorail which were made following the initial CEVP analyses. However, space is limited so it is not possible to elaborate in this article.

5. SUMMARY

In this article, a recently-developed risk-based method for the estimation and management of cost for complex, infrastructure projects has been presented. Through this process it is possible to remedy long-standing problems in cost estimating for complex infrastructure and tunneling projects. The procedure, called the Cost Estimate Validation Process, or CEVP, uses risk and uncertainty methods to modify the normal cost estimate to produce a "range of probable cost". The concept incorporates principles similar to those used for risk analyses which have been applied to several specialized tunneling projects.

The procedure has been applied to a set of projects in Washington State (USA) estimated at about US $25 billion and to many smaller projects. The process includes explicit identification of high-cost and schedule risk drivers – leading to an ability to develop explicit risk management, plans early in the project's development, directly from the CEVP process. Initial results are favorable, with the first public, competitive tender falling within the estimated "range of probable cost".

There is National and International interest in the procedure (Reilly, 2003c). In the U.S., the Federal Transit Agency has applied CEVP and other risk-based estimating procedures and has issued a draft policy statement (Circular 22) requiring risk to be included in cost estimates.

4.1 Key Points and Recommendations:

1. The final cost of a project is subject to many variables, assumptions and conditions which significantly influence the range of probable projected costs. Therefore, a single cost number represents only *one possible result* and is dependent on variables which are not all directly controllable or absolutely quantifiable
2. As an industry we need to do a better job of estimating the "range of probable costs" of projects – to do so it is necessary to use a logical process incorporating risk and probability
3. A new approach – the Washington State Department of Transportation's Cost Estimate Validation Process (CEVP), and a simpler Cost-Risk-Assessment (CRA) process, have been successful in producing more realistic ranges of probable costs for several complex projects
4. The CEVP process allows the project team to explicitly quantify risks and to develop more strategic risk management plans for the explicitly identified risk events
5. The more realistic cost ranges have increased public confidence in the Washington State Department of Transportation's ability to estimate and manage complex, infrastructure projects
6. The CEVP process is currently being evaluated at the US Federal level to determine specific methodologies for application to US transportation and Infrastructure projects
7. The CEVP process explicitly quantifies potential risk events and their contribution to "probable cost" – allowing explicit risk management plans to be developed early in the project

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